Weak microlensing effect and stability of pulsar time scale

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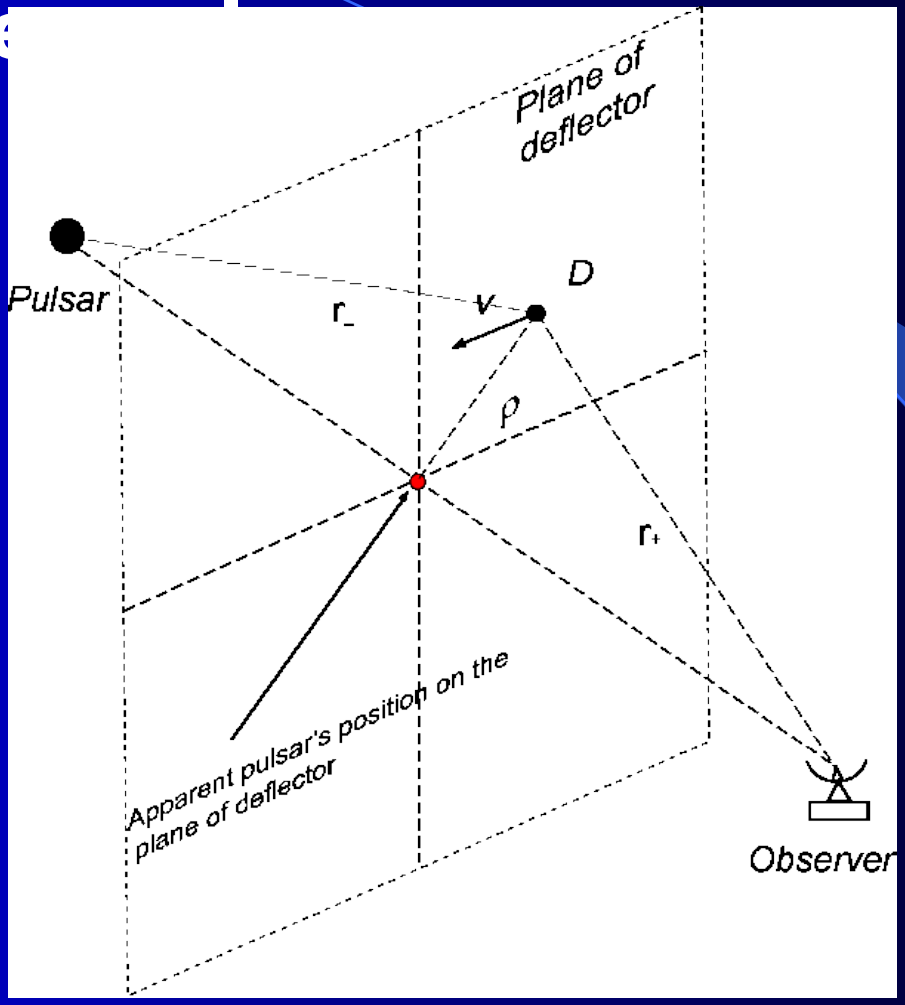

Schematic picture of origin of weak microlensing effect. D-deflecting object.

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Propagation of pulsar electromagnetic wave can be described by using *eikonal* formalism.
Influence of gravitational deflector leads to a small phase shift :

$$\Delta\psi = \frac{r_g \omega}{c} \ln \frac{4 r_- r_+}{\rho^2}$$

The phase shift changes in time, because ρ is variable

$$\Delta\psi_2 - \Delta\psi_1 = \frac{r_g \omega}{c} \ln \left| \frac{\rho_1^2}{\rho_2^2} \right|$$

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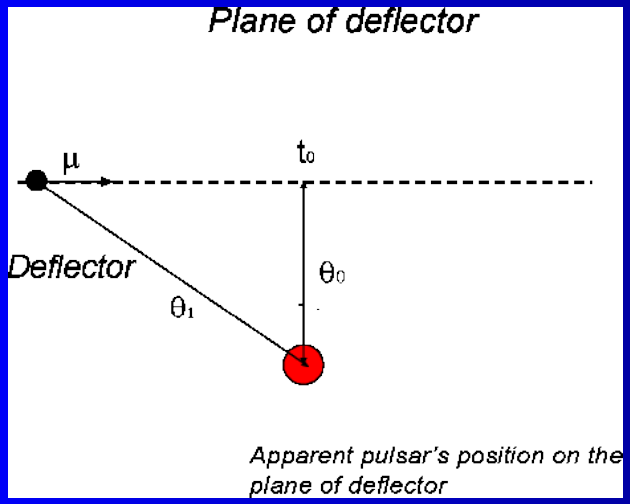

Plane of deflector

It's convenient to consider this problem on the *"plane of deflector"*; then all linear measures will be converted to angular ones. Time of Arrival (TOA) residuals will be as:

$$\delta T = -\frac{r_g}{c}\ln\left[\frac{\theta_0^2 + \mu^2(t - t_0)^2}{\theta_0^2 + \mu^2 t_0^2}\right]$$

Here, θ_0 – minimum of angular distance between deflector and pulsar

μ – proper motion of deflector (relative to pulsar)

t_0 – epoch of the minimum distance between *D* and *line of sight*

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Value θ_0 depends on density of population of massive bodies (stars, MACHOs, etc.) on celestial sphere in the pulsar neighborhood. Only bodies between the observer and the pulsar have to be taken into account.

There're several millisecond pulsars in dense populated regions of Galaxy. Let's take two of them (B1937+21, J1643-1224) for further estimation. Parameters, which are essential for estimation, are listed in the table below.

Pulsar	θ_1	μ	θ_0	t_e
B1937+21	2.5''	~10 mas/yr	1.5''	300 yr
J1643-1224	7.3''	~10 mas/yr	4.7''	900 yr

θ_1 – angular distance between the pulsar and the nearest body (from accepted model of Galaxy)

θ_0 –minimum of angular distance between deflector and pulsar (Monte-Carlo)

μ – proper motion of deflector (relative to pulsar)

t_e – time span of remarkable interaction

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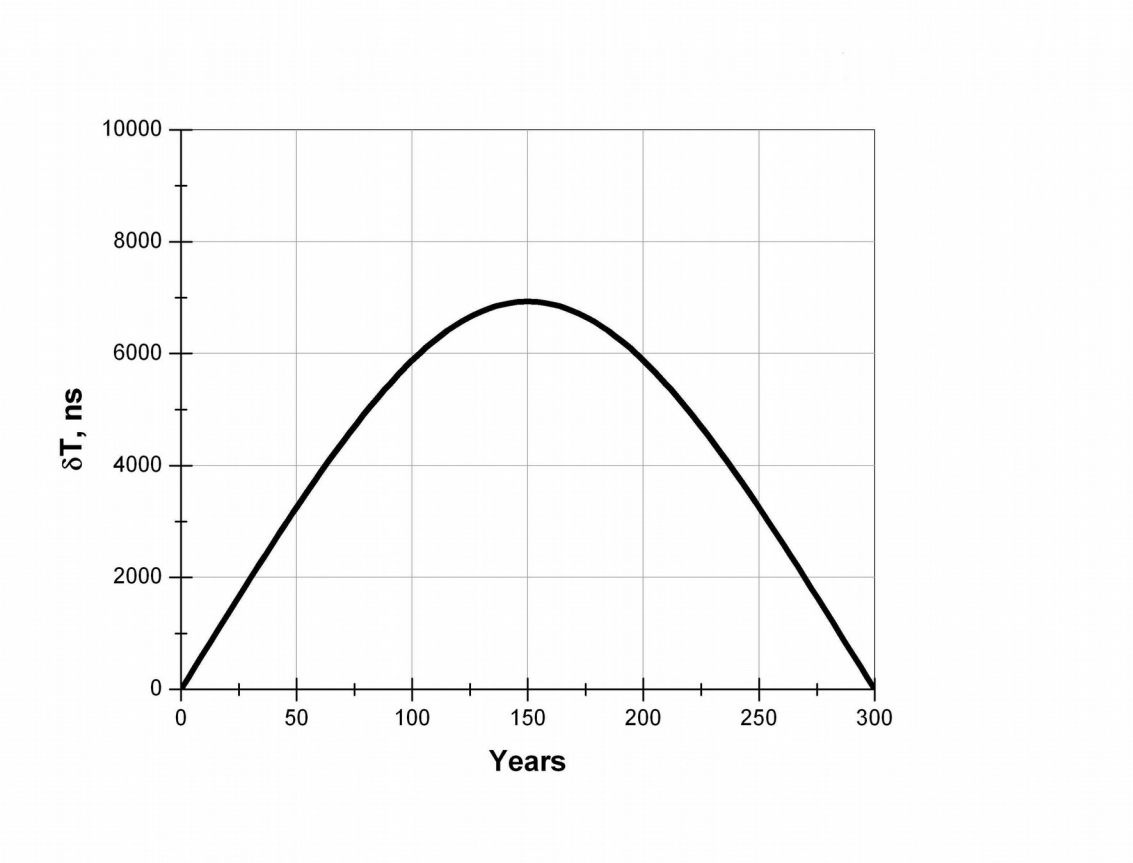

TOA residuals, caused by the effect; no fitting conducted yet. Only trends of cubic and higher-power orders will survive after the fitting procedure. Linear and quadratic trends will redefine an apparent pulsar period *P* and its first derivative *dP/dt*.

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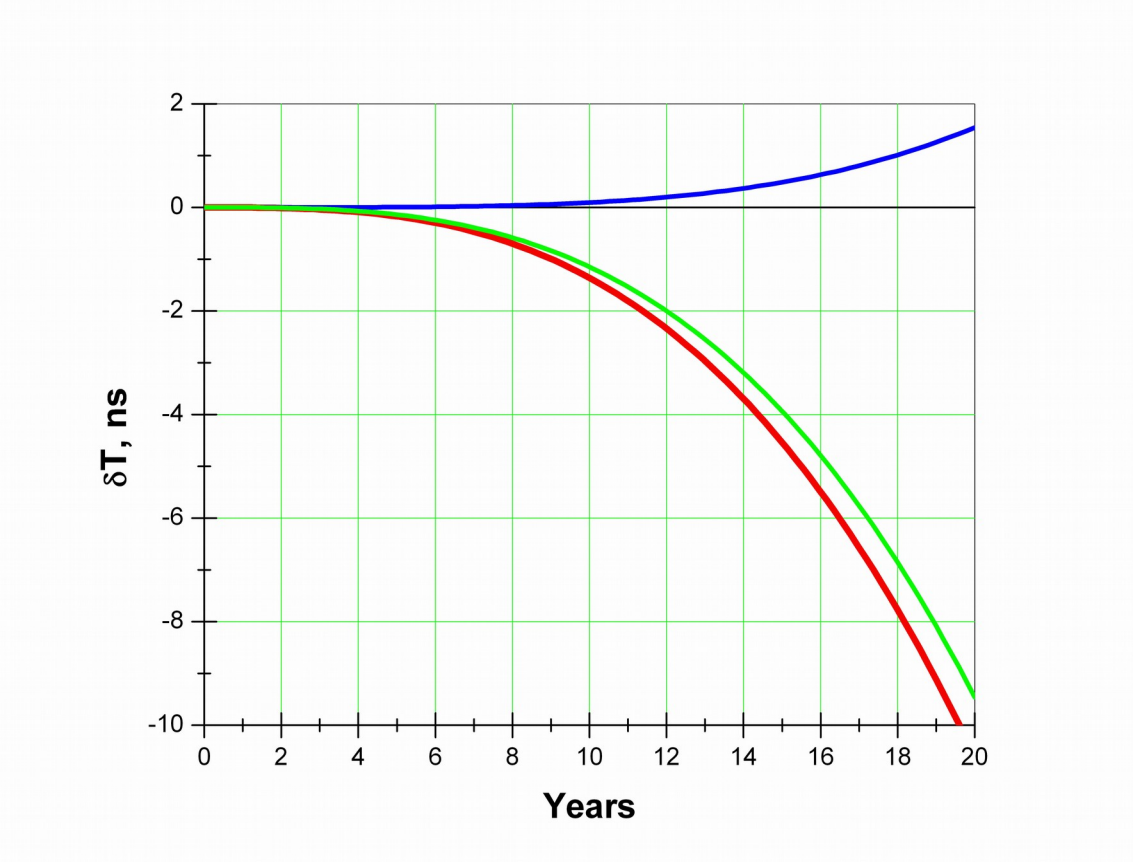

TOA residuals due to weak microlensing effect. The blue curve corresponds to t_0 =0, green one to t_0=50 years and red one to t_0=100 years.

In 20 years span, TOA residuals due to the effect accumulate ~10 ns

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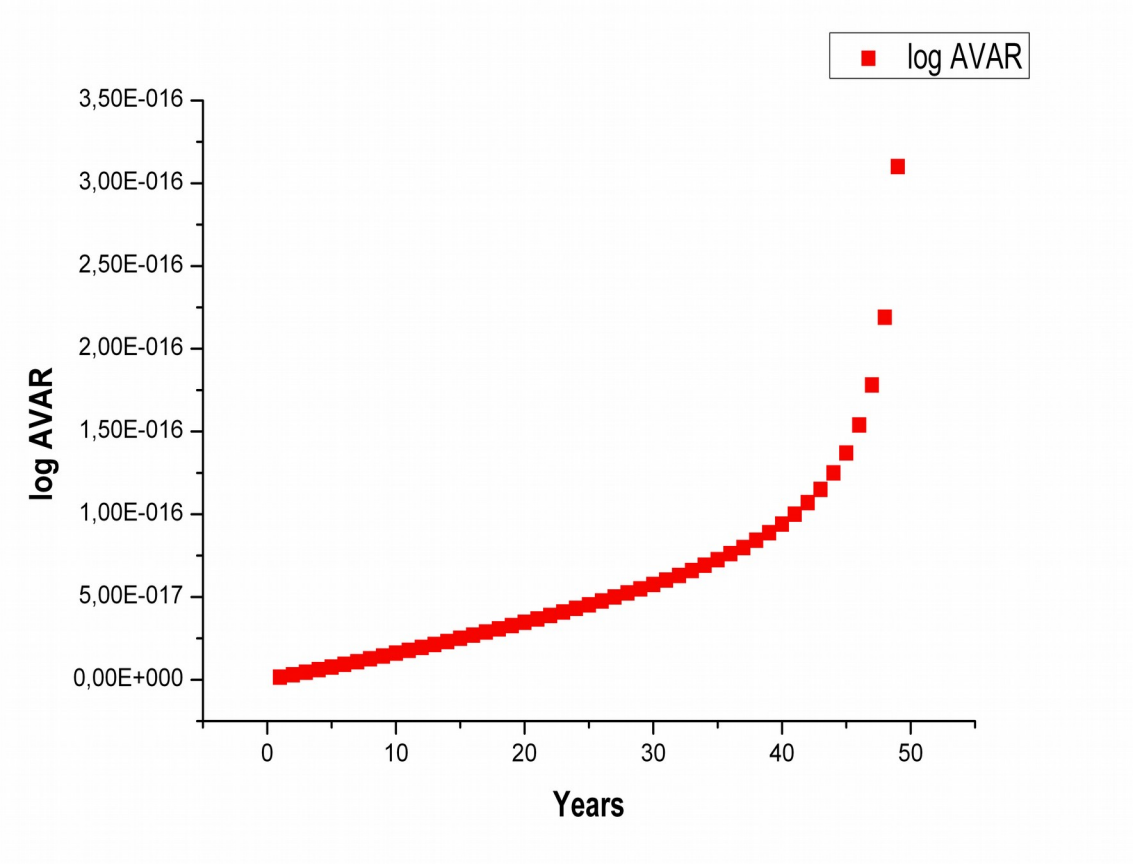

Allan Variance (AVAR) which appears from a weak microlensing effect.

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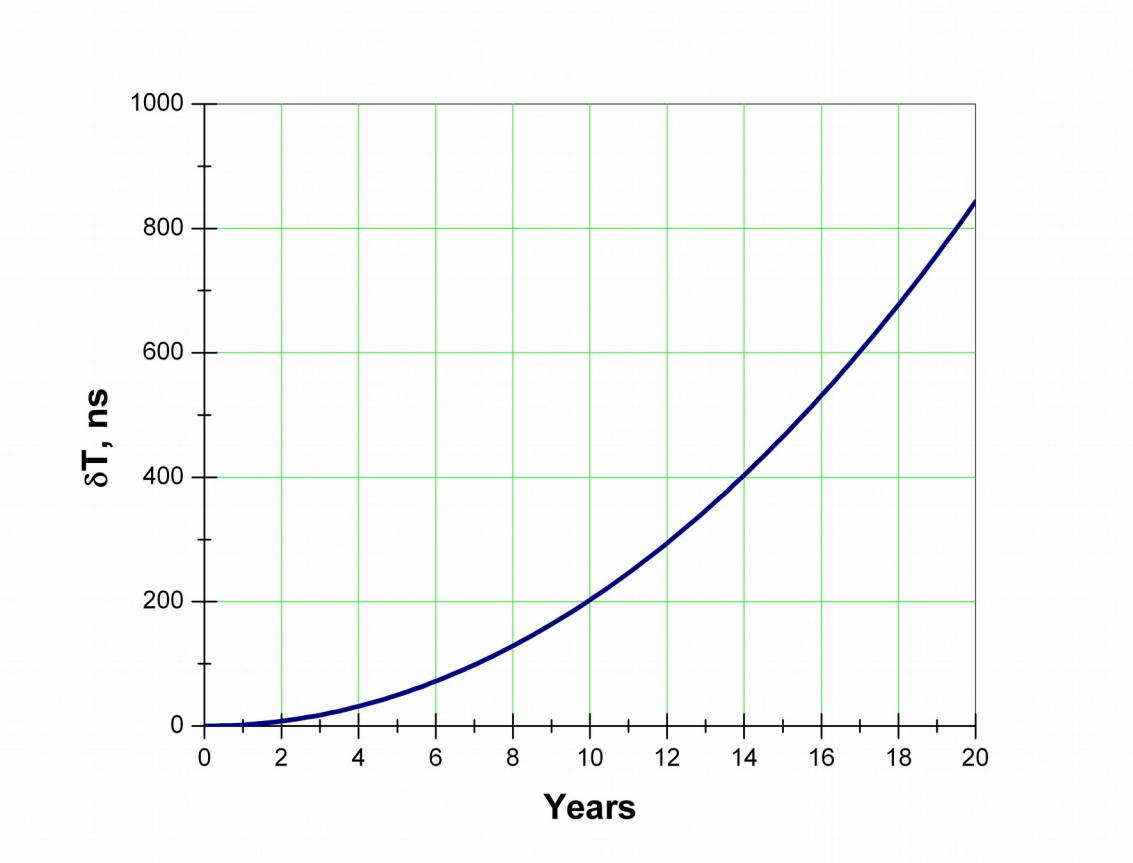

TOA residuals due to the effect can be significant, if θ_I (angular distance between the pulsar and the nearest body) is much smaller than average. The plot represents situation when θ_0=0.1 mas. This situation has **~0.5%** probability in case of B1937+21; this probability is much greater for pulsars in globular clusters.

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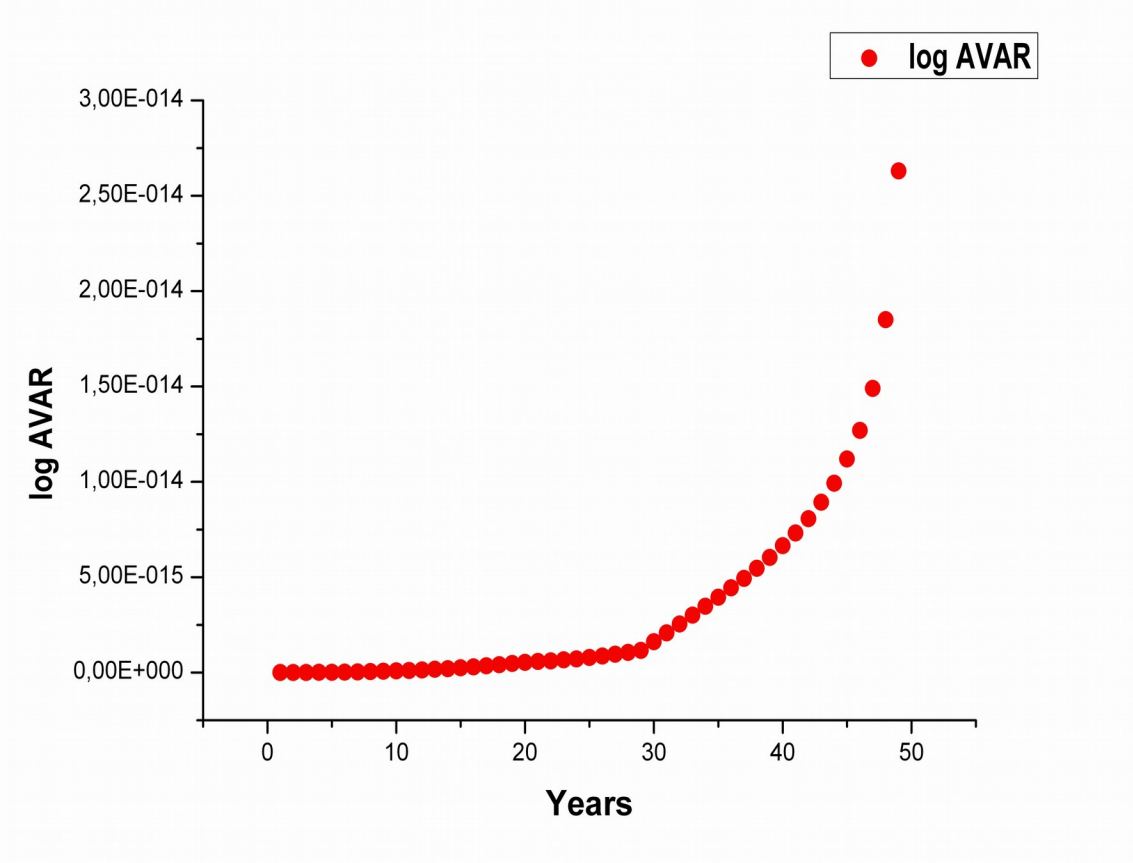

AVAR from the weak microlensing effect in globular clusters.

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Conclusions

- Average TOA residuals due to a weak microlensing effect is about 10 ns (B1937+21) in 20 years span.
- TOA residuals can be effectively set to zero by using higher order terms in fitting procedure (not for pulsars in globular clusters)
- TOA residuals can be much greater if pulsar is located in a globular cluster.
- The pulsars in globular clusters can’t be recommended for using in PT scale.